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STELLAR MOVEMENTS AND THE STRUCTURE OF THE UNIVERSE: REVIEW.[1]

By J. H. Moore.

The ultimate aim of all studies in stellar astronomy may be regarded as the solution of the problem of the constitution and structure of the universe; the determination of the relations existing between its members, and the nature and organization of this great system. Whether the investigations lie in the field of the accurate determination of star places, stellar parallax, the brightness of stars, radial velocities or are concerned with the classification of stellar spectra, their special interest, from the larger point of view, arises from the bearing of the results upon this problem.

During the past decade astronomical observations have accumulated at a rapid rate. Improved methods have resulted in greatly increased accuracy, and even the mere lapse of time has contributed its part in the determination of proper motions. One branch of astronomy can hardly be said to have attained to the age of majority, since it was less than twenty years ago that the spectroscopic method in the hands of Professor Campbell first yielded accurate values of radial velocity. To-day the velocities in the line of sight of some twelve hundred stars are available.

Improvements in photometric methods, especially thru the aid of photography, have given us more reliable data on the magnitudes of the fainter stars. Even in the counting of stars noteworthy advance has been made.

The data of observation have been subjected to statistical analysis by several investigators, and some very significant relations have been brought to light concerning the distribution and movements of the members of the stellar system as well as the general form of the system itself. To these researches Professor Eddington has made notable contributions. While in the solution of the problem only the first steps can be said to have been taken, nevertheless we are able to set down some results which seem fairly well established.

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[1] Macmillan Science Monographs. By Professor A. S. Eddington. Pp. XII + 266. London: Macmillan and Co. Ltd., 1914. Price, 6s net.

Professor EDDINGTON has taken the occasion in preparing the present monograph of presenting the results of his own researches and those of other investigators in a form which will appeal to those who have not been able to follow the more technical memoirs, without sacrificing any of the precision of these. It is a clear and connected statement of the present state of our knowledge, as developed within the past ten years, of the structure of the sidereal universe, and an account of the methods by which this knowledge has been gained. While suffering unavoidably from the lack of historical perspective incident to this form of treatment, it gains in the clear and precise statement of the problem and the direct and logical method of attack. The segregation of the mathematical development of star streams and the methods of statistical analysis in Chapter VII and X is a good arrangement for the general scientific reader, by whom these mathematical chapters may be omitted without marring greatly the continuity of the discussion. In the opinion of the reviewer it is also the arrangement to be preferred in the presentation of the subjects to students of astronomy.

The treatise is divided into twelve chapters. In the first the data of observation are considered,—apparent position in the sky, magnitude, type of spectrum and color, parallax, proper motion, radial velocity and in some rare cases the mass and density of a star. Before entering upon the discussion and application of these data the author presents in the following chapter a general view of the form of the sidereal system, the distribution of its members and the peculiarities of their motions, so that the reader may appreciate more readily the relation to the general problem of each investigation described in succeeding chapters.

It is probable that for some time and perhaps always, most of our knowledge concerning the distribution of the stars will have to be gained from the analysis of stellar magnitudes and motions from which, on the basis of certain hypotheses, the mean distance of star groups may be inferred. There is, however, a small number of stars which are near enuf to us to permit of accurate determinations of their parallaxes. As our information concerning these may be considered reliable and fairly complete, they form a good starting point from which to proceed in a study of the stellar system. In Chapter III Professor EDDINGTON gives a list of the nineteen nearest stars, whose parallaxes are equal to or greater than 0."2 with a discussion of the extent to which this list is complete. It is perhaps surprising that the small sample should exhibit so faithfully many of the leading facts derived from more general studies. Eight of the nineteen stars are binaries, a proportion, however, which is somewhat higher than that given from statistics of spectroscopic and visual binaries. Even the phenomenon of star streaming is exhibited by them and the relative number of stars in the two streams is practically the same as that derived from the six thousand stars of Boss's Catalog. A striking peculiarity of stellar motion is indicated in that the least luminous stars appear to have a mean linear velocity much greater than that of the brighter ones. This point should be followed up in future investigations, for the indication is so clear as to lend some probability to its reality. A further significant feature is the relative number of stars of the spectral types within this sphere. There are none of Class B, two of Class A, eleven of Classes F, G, K, and four of Class M. Now this is not at all the relative proportions of the spectral classes represented by the stars to which the data of proper motion, radial velocities, counts of stars, etc., relate. In fact, as the author points out, these catalogs, owing to the method of selecting the stars down to a given apparent magnitude favor the stars of Classes B and A, since they are the more luminous. They, therefore, give us an incorrect view of the relative numbers of early and later type stars in any definite portion of space. A distribution of stars of different spectral types within a definite volume of space, similar to that shown above by the nearest stars, has been derived recently from a more general investigation by Professor SCHWARZSCHILD. The importance of taking into account this limitation in data derived from star catalogs when applying them to statistical investigations is noted by Professor EDDINGTON as well as in this later memoir.

The simplest type of stellar motion, that in which the members of a group are found to have equal and parallel motions, is considered in the following chapter. From a knowledge of the proper motions of the individuals of a moving cluster, together with the radial velocity of a single member, the parallax of the cluster is derived. Precise and detailed information is thus afforded of the distance and hence distribution and luminosity of stars whose parallaxes are beyond the limit of measure by the direct method. For two examples of the class, the *Taurus* and *Ursa Major* clusters, this information has been derived, but for the third, the *Perseus* cluster, the data at present do not permit a determination of the parallax.

These great communities of stars are known to be moving thru space in which are distributed many other stars not of their family, and yet the individuals of the cluster preserve their motions undisturbed. This fact, as the author very clearly points out, affords important evidence that the motions of stars are due to the central attraction of the whole stellar system rather than to the individual attraction of their neighbors.

A chapter is devoted to the results of recent investigations of the solar motion, with a brief outline of the theory of its determination from the observations. On account of its importance as a fundamental unit in researches on the distribution of the more distant stars, considerable attention has been given to the determination of the direction and speed of the Sun's motion. Two recent results, the one by Professor Boss, based upon proper motions, the other by Professor CAMPBELL, derived from radial velocities, have practically superseded the older values. The two results derived by fundamentally different methods agree very well in the position of the solar apex in right ascension, but for some unexplained reason the declination is some ten degrees lower for the apex determined from radial velocities.

The speed in kilometers per second of the Sun's motion is furnished in addition to its direction by the radial velocity method.

In Chapter VI the author gives a clear account of the two-stream theory, based largely upon his own researches. Here it is shown that the fundamental peculiarity of stellar motion, that of the tendency of the stars to move in two favored directions, is indicated by the proper motions of stars from all regions of the sky, and in a general way is confirmed by radial velocity observations. The direction and speed of the two streams, as well as the relative distribution of the stars between the two drifts, are deduced. From an investigation of the mean distances of the members of the two drifts, he concludes that the mixture of the stars in the streams is fairly complete. That the two-drift theory and the alternative point of view offered by SCHWARZSCHILD in his ellipsoidal hypothesis represent only the most striking features of the distribution, is clearly indicated by the author. HAHN's interpretation of the phenomenon in terms of the three-drift hypothesis is shown to furnish a closer approximation to the actual distribution. Attention is also called to the fact that the important property of drift O, in that it includes all of the members of a spectral class, seems to show that this drift corresponds to some real physical system.

The mathematical theory of the two-stream and ellipsoidal hypotheses and a comparison of the distributions resulting from the two methods of analysis are treated in the chapter which follows. The essential feature of both representations is the increase of peculiar velocities of the stars in two favored directions.

A most interesting chapter is given to the discussion of a series of remarkable phenomena which are associated with spectral type. The conclusion reached independently by KAPTEYN and CAMPBELL that the average linear velocity increases continuously with the type of spectrum from Class B to Class M constitutes one of the most significant discoveries in recent astronomy. On the usually accepted order of stellar evolution it appears as if a star is born without motion and gradually acquires one, and that this motion continually increases as the star grows older. The author considers the evidence in favor of some alternative explanations which attempt to correlate the phenomenon with mass or distance, and reaches the conclusion that it is a genuine correlation between speed and spectral type, independent of either mass or distance. From a study of the mean distances and distribution with reference to the galaxy of different spectral types, the conclusion is drawn that the stars of Class B are strongly condensed in the galactic plane; that the system of A stars is very oblate, while the system of M stars is almost globular. The hypothesis of dwarf and giant stars as put forward by Professors HERTZSPRUNG and RUSSELL is carefully considered. The order of evolution to which this hypothesis leads is directly opposed to the generally accepted one which, as the author says, "has been independently confirmed by studies of stellar velocities, galactic distribution, and the periods of binary stars."

In Chapter IX an account is given of the information to be gained by counting the stars brighter than a given magnitude. The value of this method depends largely upon the accuracy with which the magnitudes are determined to which the count refers. Great weight is given to the very comprehensive investigation of counts of stars between the second and seventeenth magnitude, published by CHAPMAN and MELLOTE in 1914. These results are made the basis of a determination of the relative extension of the stellar system in the galactic plane and in a direction perpendicular to it.

Our knowledge of the structure of the stellar universe could be said to be fairly complete if we were able to determine the laws of density, luminosity and velocity for this system. The author sketches very clearly the statistical methods whose object is the determination of these laws, based upon data of counts of stars between given magnitudes, mean parallactic motion of stars of given magnitudes, parallax determinations, and the distribution of the proper motions of stars brighter than a limiting magnitude. The elegant general solution of SCHWARZSCHILD for the determination of the density and luminosity law is presented, and the results of KAPTEYN and SEELIGER discussed. While, as the author notes, the numerical results will undoubtedly be modified later, these statistical researches have already advanced our knowledge of the distribution and luminosity of the stars and point the way for a further extension of it in the future.

A chapter is devoted to the description of the interesting phenomena of the Milky Way, star clusters and nebulæ. Attention is called to the remarkable distribution with reference to the galactic plane of clusters, of planetary and extended nebulæ, and of the spiral nebulæ. Concerning a subject about which so little is known as the spectra of spiral nebulæ, it is perhaps not strange to see the statement made that the spectrum of the *Andromeda* nebula contains bright lines. The presence of emission lines or bands in this nebula, according to an observation of WOLF, has not been confirmed by other investigators employing slit spectrographs. That bright lines or bands do occur in some other spiral nebulæ is well known, but the reviewer who has observed them is not ready to subscribe to the statement that they "are of the character of those found in some of the early type stars, and are distinct from the emission lines of the gaseous nebulæ." The author regards with favor, at least as a working hypothesis, the theory which regards these spiral nebulæ as "island universes." Favorable consideration is also given to the view which seems to be gradually taking shape, that our system of stars is a great spiral, and the tentative suggestion is made that "the two star streams and the double branched spirals arise from the same cause."

In the final chapter an account is given of an attempt to develop a dynamical theory of the stellar system, based on the principle "that the stars describe paths under the general attraction of the stellar system without interfering with one another." The application of dynamics to a system in which so little is known of the kinematical relations, has, as the author admits, been attended with very little success.

Professor EDDINGTON in his "Stellar Movements and the Structure of the Universe," has drawn for us the general outline and form of the stellar system, adding where possible the details of the arrangement and relations of its members. It is a truly remarkable and striking picture which he presents. Some of the details which have been sketched may later need to be modified or possibly erased; and undoubtedly others will be added. One cannot resist the impression that in some of its main features this picture is going to endure.